Eastern Kentucky University

Encompass

EKU Faculty and Staff Scholarship

Faculty and Staff Scholarship Collection

2017

Trial 1 versus Trial 2 of the Test of Memory Malingering: Evaluating Accuracy Without a “Gold Standard”

Douglas Mossman
University of Cincinnati College of Medicine

Dustin B. Wygant
Eastern Kentucky Univeristy, dustin.wygant@eku.edu

Roger O. Gervais
University of Alberta - Neurobehavioural Associates

Kathleen J. Hart
Xavier University, Cincinnati, OH

Follow this and additional works at: https://encompass.eku.edu/fs_research

Part of the Psychological Phenomena and Processes Commons

Recommended Citation

Mossman, Douglas and Wygant, Dustin B. and Gervais, Roger O. and Hart, Kathleen J., Trial 1 Versus Trial 2 of the Test of Memory Malingering: Evaluating Accuracy Without a 'Gold Standard' (January 3, 2017). Psychological Assessment, Forthcoming.

This Article is brought to you for free and open access by the Faculty and Staff Scholarship Collection at Encompass. It has been accepted for inclusion in EKU Faculty and Staff Scholarship by an authorized administrator of Encompass. For more information, please contact Linda.Sizemore@eku.edu.

Trial 1 versus Trial 2 of the Test of Memory Malingering: Evaluating Accuracy without a "Gold Standard"

Douglas Mossman, M.D.
Department of Psychiatry and Behavioral Neuroscience
University of Cincinnati College of Medicine, Cincinnati, Ohio, USA

Dustin B. Wygant, Ph.D.
Department of Psychology, Eastern Kentucky University, Richmond, Kentucky, USA

Roger O. Gervais, Ph.D.
University of Alberta and Neurobehavioural Associates, Edmonton, Alberta, Canada

Kathleen J. Hart, Ph.D.
School of Psychology, Xavier University, Cincinnati, Ohio, USA

Address correspondence to Dr. Mossman:
Department of Psychiatry and Behavioral Neuroscience, UC College of Medicine
260 Stetson Street, Suite 3200, Cincinnati, Ohio 45219
Telephone: (513) 558-4423 • Fax: (513) 558-3823 • douglas.mossman@uc.edu

Accepted 6 January 2017 for publication in *Psychological Assessment.*

This article may not exactly replicate the authoritative document published in *Psychological Assessment*. It is not the copy of record.

Electronic copy available at: https://ssrn.com/abstract=2898221

Abstract

This study examines the accuracy of the Test of Memory Malingering (TOMM), a frequently administered measure for evaluating effort during neurocognitive testing. In the last few years, several authors have suggested that the initial recognition trial of the TOMM (Trial 1) might be a more useful index for detecting feigned or exaggerated impairment than Trial 2, which is the source for inference recommended by the original instruction manual (Tombaugh, 1996). We used latent class modeling (LCM) implemented in a Bayesian framework to evaluate archival Trial 1 and Trial 2 data collected from 1198 adults who had undergone outpatient forensic evaluations. All subjects were tested with two other performance validity tests (the Word Memory Test and the Computerized Assessment of Response Bias), and for 70% of the subjects, data from the California Verbal Learning Test–Second Edition Forced Choice trial were also available. Our results suggest that not even a perfect score on Trial 1 or Trial 2 justifies saying that an evaluee is definitely responding genuinely, although such scores imply a lower-than-base-rate probability of feigning. If one uses a Trial 2 cut-off higher than the manual's recommendation, Trial 2 does *better* than Trial 1 at identifying individuals who are almost certainly feigning while maintaining a negligible false positive rate. Using scores from both trials, one can identify a group of definitely feigning and very likely feigning subjects who comprise about two-thirds of *all* feigners; only 1 percent of the members of this group would not be feigning.

Keywords: malingering; Test of Memory Malingering; gold standard; receiver operating characteristic; latent class methods; Bayesian models

Introduction

After completing all the steps that comprise an evaluation, the fundamental question a mental health professional tries to answer is, "Given the evidence that I have assembled, what should I conclude?" In assessments done for treatment purposes, asking this question and responding to it are rarely explicit processes; instead, the clinician usually has as a set of tacit hypotheses about the patient that are tested and reconsidered as the patient undergoes treatment to alleviate whatever problems led to the clinical encounter.

In forensic mental health assessments, however, the evaluator is much more likely to ask, "What should I conclude?" explicitly (Wills, 2008). One reason is that forensic assessments typically are efforts to reach conclusions that can be stated with "reasonable medical (or scientific) certainty." Also, to the extent that an evaluator's truth-seeking efforts may not lead to the outcome the forensic evaluee desires, the forensic evaluee has an external motive to deceive the evaluator. The Third, Fourth, and Fifth Editions of the

Electronic copy available at: https://ssrn.com/abstract=2898221

Diagnostic and Statistical Manual of Mental Disorders therefore recommend having a heightened suspicion of malingering in any evaluation that takes place in a "medicolegal context."

To decide whether an evaluee is feigning or exaggerating mental symptoms or cognitive impairment, mental health evaluators use three approaches, either separately or in combination. First, mental health professionals compare what an evaluee reports or says about symptoms to what patients who have no motive to look impaired say about mental problems (see, e.g., Resnick & Knoll, 2008). Second, evaluators sometimes can identify inconsistencies between an evaluee's report and what appears in records or in other persons' outside-the-office observations (Resnick, West, & Payne, 2008). Third, mental health evaluators can use symptom validity tests (SVTs; e.g., the Structured Interview of Reported Symptoms-2 [Rogers, Sewell, & Gillard, 2010]) or performance validity tests (PVTs; e.g., the Validity Indicator Profile [Frederick & Crosby, 2000]) developed specifically to detect dishonest symptom reporting or less-than-full cognitive effort during the evaluation.

Of these approaches to detecting feigned symptoms or impairment, SVTs and PVTs are the best candidates for generating quantitative answers to the forensic evaluator's question, "What should I conclude?" The reason: SVTs and PVTs produce numerical results that could help evaluators make mathematical statements about the probability of feigning, given the evidence. If, for example, a PVT designer had previously assembled data about PVT scores from evaluees who were known for certain to have answered honestly and from evaluees known for certain to have feigned or exaggerated their impairment, the evaluator could use those data to calculate likelihood ratios or other accuracy statistics; these statistics, combined with base rate information, would lead to numerical conclusions about the probability of less-than-full effort (Mossman & Hart, 1996; Mossman, 2000).

The Test of Memory Malingering (TOMM; Tombaugh, 1996) is a popular PVT for reasons that include its relative ease of administration and the logic behind its design. Yet many authors have noted that the TOMM has limited sensitivity in detecting suboptimal effort if the results are interpreted in accordance with the standard scoring rule prescribed by the test manual (i.e., classify feigning if the Trial 2 score falls below 90% correct). This may be because savvy evaluees (or their attorneys) learn about SVTs and PVTs from legal citations (Kaufmann, 2009) and Internet resources—such as a Wikipedia article ("Test of Memory Malingering," 2016)—and can decide that during the administration of the TOMM, they should take care to not do too poorly. Other evaluees who intend to display subtle-but-phony impairment may realize by Trial 2 that the task is not as difficult as it first seems, or they may discern the purpose of the TOMM by mentally comparing it with other measures. In this respect, the TOMM likely shares a limitation with other effort measures (Denning, 2012; Guilmette, Whelihan, Hart, Sporadeo, & Buongiorno, 1996; Marshall et al., 2010).

For these reasons, several recent articles have suggested that the initial recognition trial of the TOMM (Trial 1) might be a more useful index for detecting feigned impairment (Denning, 2012; Denning, 2014; Kulas, Axelrod, & Rinaldi, 2014; Schroeder, Baade, Peck, & Heinrichs, 2011). Denning (2012) reviewed and summarized more than 20 studies available as of 2012 that report cut-off scores or accuracy indices for Trial 1, and he described findings from his own data to suggest that Trial 1 might be a more satisfactory PVT.

In all these studies and those published since, however, investigators have examined Trial 1 using a less-than-perfect criterion for non-genuine responding. Most commonly, the criterion has been another effort measure (such as the Medical Symptom Validity Test [Green, 2004]; see Denning, 2012 for an example), other sections of the TOMM (e.g., Armistead-Jehle & Hansen, 2011), or combinations of measures (e.g., Kulas, Axelrod, & Rinaldi, 2014; Schroeder et al., 2013). In some cases, investigators excluded cases that did not meet their criteria for unambiguously "poor effort" or "good effort" (e.g., failing at least two other PVTs, versus "passing" all other PVTs; see Kulas et al., 2014, p. 238). In other studies, investigators have tried to establish a specific, single Trial 1 cut-off score based on some independent criterion, such as perfect specificity when compared to a particular Trial 2 score (see Denning, 2012, Table 1 for examples) or "acceptable" specificity, usually $\geq$90% when compared with the study's criterion of truth (see Gunner, Miele, Lynch, & McCaffrey, 2012, Schroeder et al., 2013, and Kulas et al., 2014 for recent examples).

Although all the methods described in the previous paragraph represent reasonable approaches, they share a limitation: all require using an imperfect "gold standard" for the true status of subjects and/or an arbitrary, single cut-off to classify subjects. Because of this, the resulting accuracy indices incorporate systematic misclassification errors that potentially bias and limit findings. In this article, we describe results from applying latent class modeling (LCM) methods similar to those used by Mossman, Wygant, and Gervais (2012) to examine "real-world" Trial 1 responses from 1198 forensic evaluees. Our hope was that LCM techniques would let us make inferences about the diagnostic properties of Trial 1 and compare these to Trial 2 without having to use an imperfect "gold standard" to categorize study subjects.

Method

Study Subjects

Because the present research used de-identified archival data, it received a designation of "exempt" from the institutional review board of the University of Cincinnati. The data originated from 2627 consecutive evaluees who underwent outpatient assessment at the third author's office practice. Nothing in pre-evaluation information or the third author's evaluation findings suggested that any evaluee had a severe cognitive impairment (e.g., dementia or intellectual disability) that would have required special cautions beyond those normally applicable to a psychological evaluation.

Our statistical methods (discussed later in this section) required that individuals have undergone evaluation with multiple measures that test for a similar type of impression management. We therefore focused on individuals in the dataset whose evaluations included administration of the TOMM, the Computerized Assessment of Response Bias (CARB; Allen, Conder, Green, & Cox, 1997), and the Word Memory Test (WMT; Green, Allen, & Astner, 1996; Green, 2003). This requirement removed just over half the evaluees (*i.e.*, 1326 individuals) from the subject pool. The remaining 1301 evaluees included 28 persons who did not speak English well enough to take the PVTs in English. We excluded these persons from the analysis. We also excluded individuals who had undergone evaluations for treatment purposes and were not evaluated in a forensic context (e.g., Worker's Compensation Board). The treatment-oriented evaluees included 15 widows of workers who had been killed on the job or who had died from a progressive work-related condition (e.g., mesothelioma), and 60 individuals who were not seeking compensation and underwent evaluation to guide psychological treatment. The resulting sample thus included 2627 – (1326+28+15+60) = 1198 evaluees who underwent assessment related to worker's compensation claims (*n* = 897, 74.9%), their involvement in civil litigation (e.g., plaintiffs in personal injury cases, *n* = 224, 18.7%), both worker's compensation and lawsuits (*n* = 7, 0.6%), disability insurance claims (*n* = 64, 5.3%), and pension claims (*n* = 6, 0.5%).

Most (*n* = 730, 60.9%) persons in the sample were men. The sample's mean age was 40.4 (*SD* = 11.0) years; the mean education level was 11.6 (*SD* = 2.5) years. One-eighth (*n* = 148, 12.4%) of the sample subjects spoke languages other than English (including Punjabi, Mandarin, Arabic, Spanish, Polish, and Ukrainian) as their primary language, although all these evaluees completed the PVTs in English. In these 148 individuals, the mean WAIS-IV Verbal IQ score was 83.2 (*SD* = 11.6), mean Performance IQ was 86.7 (*SD* = 14.5), and mean Full Scale IQ score was 83.2 (*SD* = 11.6). Their scores were lower than the scores of the native English speakers: Verbal IQ = 97.2 (*SD* = 12.7), Performance IQ = 101.8 (*SD* = 14.4), and Full Scale IQ = 99.1 (*SD* = 13.2).

Motor vehicle accidents were the reported source of injury for 238 members (19.9%) of the sample; 893 individuals (74.5%) reported being injured at work. The reported physical problems were mainly musculoskeletal and orthopedic injuries. Primary sites of pain as specified on the Multidimensional Pain Inventory (Kerns, Turk, & Rudy, 1985) were head, face, or mouth (*n* = 121, 10.1%); neck (*n* = 136, 13.6%); shoulders or upper extremities (*n* = 223, 18.6%); lower back (*n* = 289, 24.1%); and lower extremities (*n* = 117, 9.8%). Primary psychiatric diagnoses were rendered by the third author in accordance with then-current *DSM-IV* or *DSM-IV-TR* criteria using referral documentation and all data gleaned from the assessments, which included findings from detailed clinical interviews of the evaluees plus the psychological test results.

Four-fifths of the sample had diagnoses of chronic pain (32%), anxiety or posttraumatic stress disorder (30%), or depression (17%). As the previous paragraph notes, one-tenth of the sample had primary pain sites that involved the head and face, and about one-half these individuals reported physical problems that could have involved brain trauma. The remaining evaluees had problems such as temporomandibular joint pain. After accounting for other psychiatric conditions, 15 (1.3%) members of the total subject group had primary diagnoses of head injury, and two (0.2%) had other neurological conditions. These 17 subjects were not undergoing evaluations for purposes of neuropsychological assessment. They had already undergone detailed neuropsychological evaluations elsewhere that had detected no neurological or neuropsychological impairment severe enough to prevent them from returning to work, but the presence of other, comorbid psychological issues had not necessarily been evaluated. These subjects (along with the others in our sample) had no apparent, neurologically based reason for not being able to "pass" performance validity tests. None had obvious impairments in conversation, and all were community-living outpatients (i.e., they did not come from residential or hospital treatment settings) who traveled independently or with relatives for their assessments.

Test Data

The WMT, CARB, and TOMM yield several scores from which an evaluator might make judgments about possible feigned cognitive impairment. For this study, we used:

- a total WMT score obtained by combining the immediate recognition (IR), delayed recognition (DR), and consistency scores;
- a final CARB score calculated from all three blocks of the instrument, with imputed scores based on the stopping rules if evaluees scored 100% on a block;
- the simple numerical results from Trial 1 and Trial 2 of the TOMM.

Most (843, or 70.4%) of the subjects also had test data available for an additional proposed measure of malingering, the Forced Choice trial of the California Verbal Learning Test–Second Edition (CVLTFC; Delis, Kramer, Kaplan, & Ober, 2000), and we included these subjects' numerical scores in our analyses.

Approaching the Data without a Gold Standard

Because forensic mental health professionals rarely know *for certain* whether a given evaluee has responded genuinely, investigators have tried to assess the accuracy of PVTs and SVTs in two ways. In so-called "known group" or "criterion" studies, investigators evaluate discrimination power of validity measures by comparing the responses of evaluees *believed* to be responding genuinely with evaluees *believed* to be feigning or exaggerating problems. In “simulation” studies, investigators ask non-symptomatic (“healthy”) subjects to answer test items as the subjects believe persons with mental disorders or cognitive impairments would. The investigators then compare these subjects’ simulated responses to those of persons who actually are mentally ill or cognitively compromised but who have no known motivation to look more ill or impaired than they really are.

Each of these methods has limitations, however. Because no gold standard establishes the truth in known-group studies, investigators must either exclude ambiguous cases or accept that some feigning or non-feigning subjects may be misclassified. In simulation studies, subjects’ true status is known, but investigators do not know how well simulators’ behavior resembles the efforts of real feigners who undergo real forensic evaluations.

To get around these problems, Mossman and colleagues (2012) used an approach based on principles of latent class modeling (LCM) (Uebersax & Grove, 1990), which has helped investigators in several areas of medicine (Henkelman, Kay, & Bronskill, 1990) and in related fields (e.g., Choi, Johnson, Collins, & Gardner, 2006; Jafarzadeh, Johnson, & Gardner, 2016 [cattle infections]). Broadly, this approach involves developing a data model that includes the accuracy parameters, then obtaining data from subjects who have undergone evaluation for a condition with more than one diagnostic method. If the resulting number of data categories exceeds the number of parameters in the data model, it may be possible to identify those model parameters—which would mean that the investigator could specify the diagnostic methods’ accuracy parameters without ever knowing the true status of the subjects.

ROC Analysis

Most reports on efforts measures refer to a single PVT score or “cut-off.” For example, the standard interpretation of the TOMM is that a Trial 2 score below 90% indicates feigned memory impairment, and reports on the accuracy of the TOMM typically refer to single values of sensitivity and specificity associated with this cut-off. In our view, however, this approach to interpreting results omits two key considerations relevant to understanding the information that PVTs produce.

First, PVTs have several possible scores, and the lower a score, the stronger the evidence for non-genuine responding. Use of receiver operating characteristic (ROC) analysis allows the investigator to evaluate the discrimination characteristics of a PVT at several cut-offs and to quantify trade-offs between sensitivity and specificity as the cut-off is moved through the test’s full range of possible operating points. Knowing sensitivity and specificity at several cut-offs allows one to create a ROC graph for a test, which is a plot of the test’s true positive rate (*tpr*, which equals test sensitivity) as a function of the false positive rate (*fpr* = 1 – test specificity). Because a finite number of cut-offs is actually used, the points that represent (*fpr*, *tpr*) pairs may be connected by line segments, and the areas underneath each segment (calculated using the trapezoidal rule) can be summed to find a nonparametric estimate of the total area under the ROC curve (AUC). AUC is a useful summary of accuracy that, in the present application, equals the probability that the PVT will correctly classify two randomly chosen subjects—one feigning and one responding honestly—by assigning a lower score to the feigning subject. An AUC of 1.0 would imply perfect sorting, and an AUC of 0.5 would imply no-better-than-chance discrimination between invalidly responding and validly responding subjects.

Second, PVT results are evidence that, if used optimally, should alter or revise one's belief about the probability that the evaluee is feigning impairment. This Bayesian interpretation of a PVT result implies that we would like information about the tests that let an evaluator answer the question, "Now that I have this result, what should I believe about this evaluee?" If we can somehow establish the values of the ROC parameters for the PVT, the answer to this question will follow directly.

Our analyses used a Bayesian framework to locate values for the ROC parameters of the PVTs we studied. Essentially, our data analysis asked, "Given these subjects' PVT results, what should we make of them? Given our study data, what should we believe about the ROC accuracy parameters for these PVTs?" To answer this question, we set about obtaining estimates of (*fpr*, *tpr*) pairs using the nonparametric model described by Albert (2007) and used in previous studies by Mossman and colleagues (Mossman et al., 2010; Mossman et al., 2012). Bayesian estimation methods summarize knowledge about unknown parameter values using ''posterior'' distributions that represent the probability that a parameter has a particular value, given the observed data.

Bayes's Rule states that the posterior probability of a parameter's value is proportional to the likelihood of observing the data given that parameter value, multiplied by a "prior" probability of the parameter's value. This approach is somewhat like maximum likelihood estimation (which provides point estimates for the parameter values that are most likely to have generated the observed data), and when priors are chosen so as to be "non-informative," Bayesian and MLE results are often numerically similar (Carlin & Louis, 2009). Bayesian results differ from MLE results in an important theoretical way, however. MLE results tell us things like, "We can have 95% confidence that a confidence interval constructed with this estimation method will contain the true value of a parameter." Bayesian estimation summarizes *what we should believe* about a parameter's true value via its "credible interval," which represents a direct probability statements about the parameters—for example, "the probability is 95% that parameter θ for PVT j lies between x and y" or "given John Doe's PVT result, the probability that he feigned impairment is greater than 95 percent."

We ran our Bayesian analyses in OpenBUGS, a free, open-source software program that is one of the successors to WinBUGS (Lunn, Spiegelhalter, Thomas, & Best, 2009). Like WinBUGS, OpenBUGS lets investigators use Markov chain Monte Carlo (MCMC) methods (Gelfand & Smith, 1990; Geman & Geman, 1984; Metropolis, Rosenbluth, Rosenbluth, Teller, & Teller, 1953) to generate posterior distributions from which the investigators draw Bayesian inferences about the parameter values. MCMC methods lead to inferences about posterior distributions for parameters of complex models if (as we hoped would be true for our data) mild regularity conditions are met such that a Markov chain will converge to a unique ‘‘target’’ distribution. This target distribution consists of the most plausible ranges for the parameters of interest—here, the parameters that, taken together, describe the accuracy of the PVTs we studied.

To use MCMC methods for our Bayesian analysis, we prepared OpenBUGS code modified from the WinBUGS code used by Mossman and colleagues (2012). The transition kernel made the target distribution of the resulting Markov chain the joint posterior distribution of model parameters. To assure model identification, we found it necessary to use a modestly informative Beta (6.3, 13.3) prior for the prevalence of feigning, which implies that one is 99% sure the true value lies between 0.1 and 0.6. We ran two parallel MCMC chains, and these appeared to converge after approximately 500 updates. We ran each chain for 20,000 updates, discarded each chain's first 10,000 "burn-in" updates, and used the remaining 10,000 values for inference.

Ideally, we would have used both Trial 1 and Trial 2 simultaneously in our analyses. We found, however, that doing so caused the TOMM scores to "overwhelm" the other data—that is, the OpenBUGS algorithm identified a model in which the TOMM was taken to be the truth, a conclusion at odds with what is known regarding the TOMM's limited sensitivity. We therefore analyzed the accuracy of Trial 1 separately from Trial 2, by using either a combination of the WMT, CARB, CVLTFC, and Trial 1, or a combination of the WMT, CARB, CVLTFC, and Trial 2.

"Agnostic" and "Partial Truth" Analyses

We approached our data analyses in two ways, which (following Mossman et al., 2012) we term *agnostic* and *partial truth*. In the agnostic approach, we used as the sole information available four PVT scores from the subjects (i.e., WMT-CARB-CVLTFC-Trial 1, or WMT-CARB-CVLTFC-Trial 2). Consistent with the comments above, the agnostic approach completely avoids the problem of trying to establish the group membership of each subject before attempting to estimate accuracy parameters; it simply lets the PVT data tell the story.

One might argue, however, that the agnostic approach excludes some information from the analysis if we know enough to classify *some* of the subjects as honest or invalid responders with virtual certainty. We therefore should incorporate this partial-truth information into the parameter estimation process.

One source of additional information about the model parameters estimated from the WMT-CARB-CVLTFC-Trial 1 scores is our knowledge of the subjects' Trial 2 scores. The motivation for making inferences about malingering based on TOMM Trial 1 rather than Trial 2 is not just shorter administration time, but the belief that by the second trial, some evaluees realize that the recognition task is not as difficult as first appearance suggests. This means that using the standard cut-off, Trial 2 results are highly specific, and as the results presented in the next section show, false positive interpretations are rare enough to be negligible.

For our partial truth analyses of the WMT-CARB-CVLT-Trial 1 data, we assigned 146 subjects to a "definitely responding invalidly" group. This group included 125 subjects who scored below 90% on Trial 2, plus an additional 21 subjects who scored within or below the random responding range on at least two other PVTs (that is, below 65% on the DR or IR section of the WMT, and below 58% on the CARB). Such results, we reasoned, could not reflect valid responding: the study data came from an outpatient office to which most subjects had traveled independently, and the subjects did not have conditions such as dementia that could lead to genuine, no-better-than-chance responding. We also assigned 35 subjects to a "definitely *not* feigning" group. All these subjects had attained the highest possible scores on all the SVTs. Here, we reasoned that whether a subject intended to engage in impression management or not, a perfect score on all PVTs implied that the subject was not using these measures to feign impairment.

Results

On the PVTs examined for this study, the subjects produced the following results (summarized as mean percentages of correct answers ± *SD*, with the range of results in parentheses):

WMT:	88.3±13.5 (35–100)
CARB:	94.9±11.3 (15–100)
TOMM1:	90.1±12.7 (34–100)
TOMM2:	96.3±10.6 (20–100)
CVLTFC:	88.7±14.1 (0–100)

[place Table 1 about here]

Table 1 shows the AUC estimates (with 95% credible intervals) for the four PVTs under the agnostic and partial-truth data assumptions. As was true in Mossman and colleagues' (2012) study, all PVTs outdid chance sorting of feigned versus genuine cognitive impairment, with the WMT providing superior discrimination.

[place Figures 1, 2, 3, and 4 about here]

For our present purposes, however, the key finding is that agnostic and partial-truth assumptions yielded similar results. We show this graphically in Figures 1, 2, 3, and 4. Figures 1 and 2 show ROC graphs for the data runs that used Trial 1; Figures 3 and 4 show the ROC graphs from the data runs that used Trial 2. Visual inspection confirms what Table 1 shows numerically: the AUCs for the studies are similar, and the ROC operating points occupy positions in the ROC square that are similar whether one assumes completed ignorance or partial information about the feigning status of some evaluees.

[place Figures 5 and 6 about here]

We turn now to our chief area of interest, the performance of Trials 1 and 2 of the TOMM. Figure 5 shows the ROC graphs for Trial 1 and Trial 2 under the agnostic data model, and Figure 6 contains the graphs derived from the partial truth model. Inspection of both Figures shows that Trial 1 is associated with a much larger AUC, but the ROC graphs cross each other close to the left vertical axis. This means that AUC alone may not be an adequate basis for comparing the discriminatory power of the two trials.

[place Tables 2 and 3 about here]

Tables 2 and 3 provide detailed bases for judgments about what scores on Trials 1 and 2 imply. As implemented in our OpenBUGS code, estimating operating points required grouping the TOMM scores into ordinal categories. We grouped the subjects' TOMM Trial 1 and Trial 2 scores such that they fell into the 10 categories shown in the "score" columns of Tables 2 and 3. The "percentage of subjects" columns show the proportion of subjects who fell into each category.

One formulation of Bayes's Theorem expresses the *posterior odds* as the product of the *prior odds* and the *likelihood ratio*. Here, we are interested in these relationships as they relate to the presence of feigning (denoted as M, for "malingering") and to a given test result T. We can therefore write:

$$O(M : \neg M | T) = \Lambda(M : \neg M | T) \bullet O(M : \neg M)$$

where the odds, $O(\bullet)$, equals p(•)/[1−p(•)], "¬" is the symbol for logical negation, and $\Lambda(\bullet | T)$ is the likelihood ratio associated with T. We next introduce the *stratum-specific likelihood ratio* (*SSLR*; Pierce & Cornell, 1993) to denote the likelihood ratio associated with a particular stratum or category of test results. The *SSLR* relates directly to a ROC graph in that the *SSLR* equals the slope of that portion of the graph that corresponds to the test result category. Thus, in Figures 5 and 6, the 10 segments that make up each ROC graph have slopes that equal the *SSLRs* for the respective test-result categories. Readers can gain a rough idea of the *SSLR*s from examining Figures 5 and 6; the actual *SSLR* values (to two significant digits) appear in Tables 2 and 3. Note that one calculates the $SSLR_k$ for T_k, a test result that falls into category k, from the (fpr, tpr) pairs as follows:

$$SSLR_k = \frac{tpr_c - tpr_{c-1}}{fpr_c - fpr_{c-1}}$$

where $c = \{0, 1, 2, ..., K\}$, $c = \{1, 2, ..., K-1\}$ are the nine (fpr, tpr) pairs that correspond to the cut-offs that delimit the K result categories, $fpr_{c-1} = tpr_{c-1} = 1$, and $fpr_{c=K} = tpr_{c=K} = 0$.

To calculate the post-test probabilities shown in Tables 2 and 3, we assumed that the prevalence or pre-test probability of feigning, p(M), is 0.3, an assumption supported by the findings shown in Table 1. Therefore, the pre-test odds of feigning, $O(M : \neg M)$ was 3:7, and the values shown for p(M| T1) and p(M| T2) come from the product of $^3/_7$ and the SSLR values.

As was true for the AUCs shown in Table 1, Tables 2 and 3 show that the results under the agnostic and partial-truth assumptions are similar and permit a single set of judgments about various Trial 1 and Trial 2 scores:

- Two-thirds (65.5%) of the subjects had Trial 1 scores of 46 correct or better. Concerning these subjects (or future subjects drawn from a sufficiently similar population), it would be reasonable to say that their Trial 1 performance means they have a below-base-rate probability of feigning or exaggerating cognitive impairment. In a few cases, however, Trial 2 scores might alter this opinion (as we explain further below).

- About one-sixth of our subjects (15.9%) had Trial 1 scores of 42 to 45. Such results provide less clarity about subjects' intentions. Another 8% had scores of 37 to 40; these results are strong (but not certainty-inducing) evidence of feigning impairment.

- An evaluee who gets 36 or fewer answers correct on Trial 1 is almost certainly feigning or exaggerating cognitive impairment. Just 10.7% of the subjects did this poorly. Thus, if one required this level of certainty before declaring that an evaluee is feigning, one would identify little more than a third of those evaluees who actually were feigning.

- No score on the Trial 2—not even all 50 correct—rules *out* malingering, although a perfect score is evidence that favors genuine responding.

- A Trial 2 score of 49 does not favor a conclusion for or against feigning.

- One out of 17 subjects in our study (N = 69, 5.8%) got Trial 2 scores of 45 to 48. Under the customary rules of test interpretation, one would not regard scores in this range as indicative of feigning. Yet a score of 47 or 48 is good evidence of feigning, and scores of 45 and 46 are strong evidence of doing less than one's best.

- One-tenth (10.4%) of the subjects scored below 45 on Trial 2, the cut-off for feigning that the TOMM manual (Tombaugh 1996) prescribes and that most neuropsychologists use for result interpretation. Although we can be highly confident that these subjects were performing below their true level of functioning, they represent only a third of all the subjects who were feigning or exaggerating their cognitive impairment.

[place Table 4 about here]

Table 4 provides another way to understand our findings. There, we show the TOMM Trial 1 and Trial 2 scores for all 1198 subjects. One sees that according the TOMM manual's criterion, 125 (10.4%) of all the subjects scored low enough on Trial 2 to be deemed feigners. If one adds to this group any subject whose Trial 1 or Trial 2 score implies that the posterior probability of feigning was 0.99 or greater, then an additional 36 feigners (3.5% of all subjects) are detected. An additional 89 subjects (7.4% of the total group) had a greater-than-80% posterior probability of suboptimal effort.

Thus, 250 subjects had at least an 80% probability of feigning or exaggerating impairment. If the base rate of feigning among the subjects was exactly 30%, then 359 subjects actually were feigning. Based on their posterior probabilities, 241 of the 250 subjects in the at-least-80% feigning categories were *actually* feigning or exaggerating. Therefore, the at-least-80% feigning categories contain 241 actual feigners (that is, about two-thirds of *all* feigners), plus 9 of the 839 non-feigning subjects. Put another way, designating all at-least-80% subjects as feigners would *miss* one-third of the actual feigners and would incorrectly identify 1% of the honest subjects.

One final feature of Table 4 deserves mention: it illustrates the presence of ambiguous results. Above, we explained that Trial 1 scores ≥46 support genuine responding. Yet six of the subjects who produced such scores had Trial 2 scores of 47 or 48, strongly suggesting feigning. The best explanation: these individuals were giving sub-optimal effort, evidenced by Trial 2 scores that showed no improvement over Trial 1, or (in two cases) worse performance.

Discussion

Although questions about evaluees' motivation and the validity of findings often arise in research and clinical treating settings, most (if not all) forensic mental health evaluations occur under conditions that require examiners to consider explicitly whether interview findings and test results reflect feigned or exaggerated impairment. Many combinations of motivations and situational incentives can make malingering an attractive choice, and feigning or exaggerating neurocognitive problems is a recognized coping strategy for some forensic evaluees involved in civil and criminal litigation (Resnick & Knoll, 2008). In outpatient evaluation settings, examiners often have limited observational data from which to judge the genuineness of reported neurocognitive impairment, which helps to explain the popularity of using scales that are "embedded" within psychological test materials or tools developed expressly to detect feigned or exaggerated impairment. In addition, embedded or malingering-specific effort measures often allow evaluators to render judgments about malingering for which they can cite numerically based empirical support.

Our approach to examining and comparing inferences from Trials 1 and 2 of the TOMM differed from other investigators' studies in two ways. *First*, we used other PVT scores to evaluate the TOMM's accuracy, but we did not try to create criterion groups based on those PVT scores. Instead, we let OpenBUGS make simultaneous, Bayesian inferences about group membership and the accuracy indices of all PVTs. To put this another way: rather than declaring that certain PVTs established the "truth" about subjects' malingering status when we know those PVTs are imperfect, we asked OpenBUGS to answer the question, "Given the data before us, what things about the accuracy of these PVTs are most reasonable for us to believe?"

Second, we recognized explicitly that the TOMM produces graded results that justify weaker or stronger beliefs about the likelihood that an individual is malingering. Rather than reduce TOMM results to "yes" or "no" based on our opinion about what level or sensitivity or specificity is appropriate, we used ROC methods to characterize the *degree* to which a particular TOMM score should alter an evaluator's pretest belief about the likelihood that an evaluee is attempting to feign or exaggerate neurocognitive impairment.

Other investigators (e.g., Denning, 2012) have reported AUCs for TOMM Trial 1 of greater than 0.90. In our study, Trial 1 AUCs exceeded AUCs for Trial 2 but fell below 0.85. We attribute this to our different way of evaluating data. We did not attempt to exclude any subjects whose performance might have been "hard" to categorize as genuine versus non-honest, a decision that virtually guarantees lower sorting accuracy.

Our results also paint a different picture of Trial 1 and Trial 2 scores than other investigators have suggested. We found that if one sets Trial 1 and Trial 2 cut-offs low enough to achieve near-certain confidence that an evaluee's effort was suboptimal, one will achieve a detection sensitivity of about 40%. If one can settle for feeling "at least 80% confident" that an individual has given less than full effort, then about 19% of our subjects had Trial 1 scores and 16% had Trial 2 scores that indicated suboptimal effort. Notice, however, that in the case of the Trial 2, this required interpreting scores of 48 or lower as indicating feigned or exaggerated impairment.

Our findings suggest some advantages that LCM methods have over approaches to evaluating malingering measures that use "known" groups of subjects or simulators. We did not have to use imperfect truth criteria or exclude ambiguous cases from our analyses, yet our results retained so-called "ecological" validity in that they came from evaluees in real testing situations. For the following reasons, however, we ask that readers view our findings with skepticism and cautiousness.

(1) Our data came from a single evaluation context. Although our findings concerning the TOMM are consistent with those of other investigators (see, e.g., Fox, 2011; Frederick & Bowden, 2009; Gervais, Rohling, Green, & Ford, 2004; Mossman, Miller, Lee, Gervais, Hart, & Wygant, 2015), they do not represent definitive judgments about the performance of the TOMM. We might well have had different findings to report had we examined data from psychiatric inpatients, from individuals who had suffered demonstrably serious brain trauma, or from criminal defendants who were facing prosecution.

(2) Although our prior-knowledge assumptions yielded similar results, our data models were not the only conceivable ones. We also attempted to evaluate our data using the conventional "binormal" ROC model and the dual-beta model recently proposed by Mossman and Peng (2016). These models have the advantage of yielding smooth curves and potential superior inferences about operating points (for further discussion, see Mossman & Peng, 2016). However, implementing these models in OpenBUGS produced highly correlated chains that converged poorly (even after 10,000 iterations) and in some cases gave results that seemed implausible (e.g., prevalence values below 0.2, and AUCs above 0.90 for several PVTs).

(3) As Uebersax (1988) notes, latent class methods yield upper bounds for accuracy because they choose underlying classes that minimize error rates. These error-minimizing latent classes can differ from the true classes if the probabilities of the empirical classes depend on covariates. Whether this actually is the case is hard to know (Spencer, 2012), but we do know that it is a clear possibility.

(4) Our method of analysis also risked unintentionally mistaking reliability for validity. That is, we assumed that the subjects' PVT scores represented valid ways of assessing (a) the subjects' responses to being tested, (b) whether subjects were trying to look more impaired than was actually the case, and (c) in the case of those who engaged in impression management, how those subjects approached the other cognitive evaluation measures that were administered during their evaluations. Our statistical methods were limited by the fact that irrelevant yet highly reliable assessment methods (e.g., assessing malingering by counting letters in the evaluee's last name) can appear very accurate. We could also run into this problem if most evaluees (including malingerers) knew about these tests and "played it straight" on the PVTs only. Many of our subjects' PVTs scores were low enough that we doubt this was the case—that is, they did so poorly on the PVTs that exaggerating or feigning impairment was the only plausible explanation for their test

results. Nonetheless, this could have happened for a subset of actually malingering evaluees.

(5) Our statistical inferences about malingering rates and PVT accuracy were based on PVT data alone, which is an approach that mental health professionals should not and ordinarily would not actually use. Usually, mental health professionals obtain additional data from the evaluation session and from outside sources (e.g., family members, treatment records) that are relevant to deciding how accurately evaluees are portraying themselves and their abilities. We did not use non-test data in our study because in general, such data are not quantified precisely and are therefore not amenable to the kinds of analysis we employed. If mental health professionals did generate such data from their assessment, however, then one could evaluate those data using the same methods we used here. If, for example, evaluators provided Likert-scale judgments about the probability of invalid responding based on their clinical data, the accuracy of those judgments could be treated as an "effort measure" to be evaluated along with other PVTs or SVTs, using the statistical approaches we employed.

(6) As is true for most investigations of PVTs and SVTs, we evaluated our data under the assumption that subjects either gave valid responses or did not. Indeed, either evaluees do their best or they don't, but those evaluees who do less than their best may feign or exaggerate with greater and lesser subtlety. Some disengaged evaluees simply do not put forth much effort (see Frederick & Bowden, 2009) but do not necessarily *intend* to perform at less than their best level. Our LCM model does not incorporate several notions that Rogers (2008) has emphasized: evaluees engage in malingering to different degrees, they have motivations that can affect PVT outcomes, and invalid responding has more causes than conscious effort to do worse than one's actual ability level. Notwithstanding this limitation, we still believe it makes sense to draw a distinction between those evaluees who engage in compliant, honest responding and those who respond to testing in other ways. That is, we can know that non-genuine response styles take various forms while still believing—consistent with the approach taken by all investigators who have tried to quantify the accuracy of PVTs and SVTs—that evaluees either perform at their full ability or do not.

Conclusion

Several recent articles have provided theoretical and data-based arguments to suggest that Trial 1 of the TOMM is better than Trial 2 at detecting suboptimal effort in neurocognitive assessments. Our findings showed that for about half the evaluees, Trial 1 data would allow an examiner to say, "This score means it's unlikely that this individual was feigning or exaggerating impairment," and to say this with at least as much confidence as a perfect Trial 2 result alone would justify. But given our data and statistical approach, Trial 1 did not outperform Trial 2 in how often it would justify an examiner's saying, "The evidence makes me virtually sure that this individual was feigning."

These TOMM-based characterizations of effort would apply only to evaluation settings similar to those that generated our study data. We hope readers will consider using the statistical techniques we have described to examine the TOMM and other measures used in psycholegal determinations. We also hope that our work will inspire development of additional ways to evaluate assessment tools used by forensic mental health professionals.

References

Albert, P. S. (2007). Random effects modeling approaches for estimating ROC curves from repeated ordinal tests without a gold standard. *Biometrics*, *63*, 593-602.

Allen, L., Conder, R. L., Green, P., & Cox, D. R. (1997). *CARB '97 Manual for the Computerized Assessment of Response Bias.* Durham, NC: CogniSyst, Inc.

Armistead-Jehle, P., & Hansen, C. L. (2011). Comparison of the repeatable battery for the assessment of neuropsychological status effort index and stand-alone symptom validity tests in a military sample. *Archives of Clinical Neuropsychology, 26*, 592–601.

Carlin, B. P., & Louis, T. A. (2009). *Bayesian methods for data analysis*. (3rd ed.). Boca Raton, FL: Chapman & Hall/CRC.

Choi, Y. K., Johnson, W. O., Collins, M. T., & Gardner, I. A. (2006). Bayesian inferences for receiver operating characteristic curves in the absence of a gold standard. *Journal of Agricultural, Biological, and Environmental Statistics, 11,* 210-229.

Delis, D.C., Kramer, J.H., Kaplan, E., & Ober, B.A. (2000). *California Verbal Learning Test – Second Edition*. San Antonio, TX: Psychological Corporation.

Denning, J. H. (2012). The efficiency and accuracy of the Test of Memory Malingering trial 1, errors on the first 10 items of the test of memory malingering, and five embedded measures in predicting invalid test performance. *Archives of Clinical Neuropsychology, 27*, 417-432. doi: 10.1093/arclin/acs044.

Denning, J. H. (2014). Combining the Test of Memory Malingering trial 1 with behavioral responses improves the detection of effort test failure. *Applied Neuropsychology: Adult, 16*, 269-277.

Fox, D. D. (2011). Symptom validity test failure indicates invalidity of neuropsychological tests. *The Clinical Neuropsychologist, 25*, 488-95.

Frederick, R. I., & Bowden, S. C. (2009). The test validation summary. *Assessment, 16*, 215-

236.

Frederick, R. I., & Crosby, R. D. (2000). Development and validation of the Validity Indicator Profile. *Law and Human Behavior, 24*, 59-82.

Gelfand, A. E., & Smith, A. F. M. (1990). Sampling-based approaches to calculating marginal densities. *Journal of the American Statistical Association, 85,* 398-409.

Geman, S., & Geman, D. (1984). Stochastic relaxation, Gibbs distributions, and the Bayesian restoration of images. *IEEE Transactions on Pattern Analysis and Machine Intelligence, PAMI–6*, 721–741. http://dx.doi.org/10.1109/TPAMI.1984.4767596

Gervais, R. O., Rohling, M. L., Green, P., & Ford, W. (2004). A comparison of WMT, CARB, and TOMM failure rates in non-head injury disability claimants. *Archives of Clinical Neuropsychology, 19*, 475-487.

Green, P. (2003). *Green's Word Memory Test for Windows: User's Manual*. Edmonton, Alberta, Canada: Green's Publishing.

Green, P. (2004). *Green's Medical Symptom Validity Test (MSVT) for Windows: User's Manual*. Edmonton, Alberta, Canada: Green's Publishing.

Green, P., Allen, L., & Astner, K. (1996). *The Word Memory Test: A user's guide to the oral and computer-administered forms, US Version 1.1*. Durham, NC: CogniSyst, Inc.

Guilmette, T. J., Whelihan, W. M., Hart, K. J., Sporadeo, F. R., & Buongiorno, G. (1996). Order effects in the administration of a forced-choice procedure for detection of malingering in disability claimants' evaluations. *Perceptual and Motor Skills, 83*, 1007–1016.

Gunner, J. H., Miele, A. D., Lynch, J. K., & McCaffrey, R. J. (2012). The Albany consistency index for the Test of Memory Malingering. *Archives of Clinical Neuropsychology, 27*, 1–9.

Henkelman, R. M., Kay, I., & Bronskill, M. J. (1990). Receiver operator characteristic (ROC) analysis without truth. *Medical Decision Making, 10*, 24-29.

Jafarzadeh, S. R., Johnson, W. O., & Gardner, I. A. (2016). Bayesian modeling and inference for diagnostic accuracy and probability of disease based on multiple diagnostic biomarkers with and without a perfect reference standard. *Statistics in Medicine, 35*, 859-876.

Kaufmann, P. M. (2009). Protecting raw data and psychological tests from wrongful disclosure: A primer on the law and other persuasive strategies. *The Clinical Neuropsychologist, 23*, 1130-1159.

Kerns, R. D., Turk, D. C., Rudy, T. E. (1985). The West Haven-Yale Multidimensional Pain Inventory (WHYMPI). *Pain*, *23*, 345–356.

Kulas, J. F., Axelrod, B. N., & Rinaldi, A. R. (2014). Cross-validation of supplemental Test of Memory Malingering scores as performance validity measures. *Psychological Injury and Law, 7*, 236-244.

Lunn, D., Spiegelhalter, D., Thomas, A., & Best, N. (2009). The BUGS project: Evolution, critique and future directions. *Statistics in Medicine, 28*, 3049-3067

Marshall, P., Schroeder, R., O'Brien, J., Fischer, R., Ries, A., Blesi, B., et al. (2010). Effectiveness of symptom validity measures in identifying cognitive and behavioral symptom exaggeration in adult attention deficit hyperactivity disorder. *The Clinical Neuropsychologist, 24*, 1204–1237.

Metropolis, N., Rosenbluth, A., Rosenbluth, M., Teller, A., & Teller, E. (1953). Equations of state calculations by fast computing machines. *The Journal of Chemical Physics, 21*, 1087–1091. http://dx.doi.org/10.1063/1.1699114

Mossman, D. (2000). The meaning of malingering data: Further applications of Bayes's Theorem. *Behavioral Sciences and the Law, 18*, 761-779

Mossman, D., Bowen, M. D., Vanness, D. J., Bienenfeld, D., Correll, T., Kay, J., Klykylo, W. M., & Lehrer, D. S. (2010). Quantifying the accuracy of forensic examiners in the absence of a "gold standard." *Law and Human Behavior, 34*, 402-417 doi: 10.1007/s10979-009-9197-5

Mossman, D., & Hart, K. J. (1996). Presenting evidence of malingering to courts: insights from decision theory. *Behavioral Sciences and the Law, 14*, 271-291

Mossman, D., Miller, W. G., Lee, E. R., Gervais, R. O., Hart, K. J., & Wygant, D. G. (2015). A Bayesian approach to mixed group validation of performance validity tests. *Psychological Assessment, 27*, 763–776. doi: 10.1037/pas0000085

Mossman, D., & Peng, H. (2016). Using dual beta distributions to create "proper" ROC curves based on rating category data. *Medical Decision Making, 36*, 349–365 doi: 10.1177/0272989X15582210

Mossman, D., Wygant D. B., & Gervais R. O. (2012). Estimating the accuracy of neurocognitive effort measures in the absence of a "gold standard." *Psychological Assessment, 24*, 815-822

Peirce, J. C., & Cornell, R. G. (1993). Integrating stratum-specific likelihood ratios with the analysis of ROC curves. *Medical Decision Making, 13*, 141-51.

Resnick, P. J., & Knoll, J. L. IV. (2008). Malingered psychosis. In R. Rogers (ed.), *Clinical assessment of malingering and deception* (3rd Edition, pp. 51-68). New York: Guilford Press.

Resnick, P. J., West, S., & Payne, J. W. (2008). Malingering of posttraumatic stress disorders.

In R. Rogers (Ed.), *Clinical assessment of malingering and deception* (3rd Ed., pp. 109-127). New York: Guilford Press.

Rogers, R. (2008). *Clinical assessment of malingering and deception*, 3rd ed. New York: The Guilford Press.

Rogers, R., Sewell, K. W., & Gillard, N. D. (2010). SIRS-2: *Structured Interview of Reported Symptoms: Professional manual*. Psychological Assessment Resources, Incorporated.

Schroeder, R. W., Buddin, W. H., Jr., Hargrave, D. D., VonDran, E. J., Campbell, E. B., Brockman, C. J., Heinrichs, R. J., & Baade, L. E. (2013). Efficacy of test of memory malingering Trial 1, Trial 2, the Retention Trial, and the Albany Consistency Index in a criterion group forensic neuropsychological sample. *Archives of Clinical Neuropsychology, 28*, 21-9. doi: 10.1093/arclin/acs094.

Schroeder, R. W., Baade, L. E., Peck, C. P., & Heinrichs, R. J. (2011). Use of test of memory malingering trial 1 as a measure of response bias. *Clinical Neuropsychologist, 26*, 564.

Spencer, B. D. (2012). When do latent class models overstate accuracy for diagnostic and other classifiers in the absence of a gold standard? *Biometrics, 68*, 559-566.

Test of Memory Malingering. (n.d.). In Wikipedia. Retrieved October 23, 2016 from https://en.wikipedia.org/wiki/Test_of_Memory_Malingering.

Tombaugh, T. N. (1996). *The Test of Memory Malingering*. Toronto, Canada: Multi-Health Systems.

Tombaugh, T. N. (2003). The Test of Memory Malingering in forensic psychology. In J. Hom, & R.L. Denney (Eds.), *Detection of response bias in forensic neuropsychology* (Volume 2, pp. 69-96). Binghamton, NY: Haworth Medical Press.

Uebersax, J. S., Grove, W. M. (1990). Latent class analysis of diagnostic agreement. *Statistics in Medicine, 9*, 559-572.

Wills, C. D. (2008). The CHESS method of forensic opinion formulation: striving to checkmate bias. *Journal of the American Academy of Psychiatry and the Law, 36,* 535–40.

Table 1. – Bayesian estimates of the areas under the ROC curve (median AUCs and 95% credible intervals) for neurocognitive effort measures under the agnostic and partial-truth information assumptions. Values are rounded to two significant digits.

Information Assumption	AUC (95% credible interval)					
	WMT	CARB	TOMM Trial 1	TOMM Trial 2	CVLTFC	prevalence
agnostic	0.91 (0.84–0.96)	0.73 (0.66–0.80)	0.83 (0.76–0.89)		0.73 (0.65–0.80)	0.29 (0.23–0.38)
	0.92 (0.86–0.96)	0.73 (0.66–0.79)		0.76 (0.69–0.82)	0.72 (0.65–0.78)	0.32 (0.26–0.40)
partial truth	0.92 (0.88–0.95)	0.73 (0.67–0.79)	0.85 (0.80–0.90)		0.74 (0.68–0.80)	0.32 (0.27–0.40)
	0.94 (0.90–0.97)	0.75 (0.69–0.80)		0.78 (0.73–0.84)	0.74 (0.68–0.80)	0.30 (0.25–0.36)

WMT = Word Memory Test
CARB = Computerized Assessment of Response Bias
TOMM Trial 1 = Test of Memory Malingering Trial 1
TOMM Trial 2 = Test of Memory Malingering Trial 2
CVLTFC = California Verbal Learning Test-II Forced Choice Trial
prevalence = estimated portion of subjects who were feigning

Table 2. – Bayesian estimates (medians and 95% credible intervals) of the stratum-specific likelihood ratio (SSLR) and calculated posterior probability of feigning for a given score on Trial 1 of the TOMM [p(*M*| *T*1)] under the agnostic and partial-truth assumptions about prior knowledge of subjects' feigning status, assuming a feigning prevalence of 30 percent. Values are rounded to two significant digits.

Trial 1 score	percentage of subjects	agnostic				partial truth			
		SSLR		p(M|T1)		SSLR		p(M|T1)	
49-50	37.8%	0.30	(0.16–0.50)	0.11	(0.065–0.18)	0.24	(0.14–0.39)	0.095	(0.056–0.14)
48	11.4%	0.28	(0.087–0.60)	0.11	(0.036–0.21)	0.31	(0.12–0.60)	0.12	(0.049–0.20)
47	8.6%	0.34	(0.12–0.78)	0.13	(0.048–0.25)	0.37	(0.13–0.78)	0.14	(0.055–0.25)
46	7.7%	0.45	(0.12–1.0)	0.16	(0.049–0.30)	0.52	(0.19–1.1)	0.18	(0.076–0.32)
45	5.4%	0.85	(0.24–2.0)	0.27	(0.092–0.46)	0.88	(0.32–2.0)	0.27	(0.12–0.46)
44	3.8%	1.3	(0.20–3.5)	0.35	(0.078–0.60)	1.5	(0.48–3.9)	0.39	(0.17–0.63)
42-43	6.7%	2.0	(0.82–5.1)	0.47	(0.26–0.69)	3.0	(1.3–7.1)	0.56	(0.35–0.75)
40-41	4.2%	10	(4.3–29)	0.81	(0.65–0.93)	14	(5.6–51)	0.86	(0.71–0.96)
37-39	3.8%	18	(6.9–92)	0.88	(0.75–0.98)	38	(11–5000)	0.94	(0.83–1)
≤36	10.4%	200	(41–1.2×10^{6})	0.99	(0.95–1)	9100	(220–1.2×10^{10})	1.00	(0.99–1)

Table 3. – Bayesian estimates (medians and 95% credible intervals) of the stratum-specific likelihood ratio (SSLR) and calculated posterior probability of feigning for a given score on Trial 2 of the TOMM [p(M| $T2$)] under the agnostic and partial-truth assumptions about prior knowledge of subjects' feigning status, assuming a feigning prevalence of 30 percent. Values are rounded to two significant digits.

Trial 2 score	percentage of subjects	agnostic				partial truth			
		SSLR		p(M| $T2$)		SSLR		p(M| $T2$)	
50	75.1%	0.48	(0.35–0.61)	0.17	(0.13–0.21)	0.44	(0.31–0.54)	0.16	(0.12–0.19)
49	8.7%	1.4	(0.67–2.4)	0.37	(0.22–0.51)	1.3	(0.63–2.4)	0.35	(0.21–0.5)
48	2.8%	24	(6.8–740)	0.91	(0.74–1)	22	(6.8–300)	0.91	(0.74–0.99)
47	1.3%	25	(4.6–19000)	0.91	(0.66–1)	26	(4.8–2.1×10^{4})	0.92	(0.67–1)
46	1.1%	210	(10–9.7×10^{8})	0.99	(0.82–1)	420	(17–1.2×10^{9})	0.99	(0.88–1)
45	0.6%	2000	(12–8.3×10^{12})	1	(0.84–1)	1.5×10^{4}	(40–8.8×10^{13})	1	(0.94–1)
43-44	1.7%	1.2×10^{5}	(40–5.9×10^{18})	1	(0.94–1)	2.9×10^{6}	(820–7.1×10^{18})	1	(1–1)
41-44	1.3%	1.1×10^{7}	(230–5.4×10^{18})	1	(0.99–1)	3.4×10^{8}	(3200–6.4×10^{18})	1	(1–1)
38-40	2.1%	2.7×10^{9}	(580–8.0×10^{18})	1	(1–1)	1.4×10^{11}	(3.9×10^{4}–9.3×10^{18})	1	(1–1)
≤37	5.3%	1.1×10^{12}	(8800–1.1×10^{19})	1	(1–1)	7.7×10^{13}	(4.2×10^{5}–1.3×10^{19})	1	(1–1)

Table 4. – Numbers of study subjects with various combinations of scores on Trial 1 and Trial 2 of the TOMM, with interpretation of performance validity. Numbers along the right and bottom margins of the table show marginal totals. Empty cells contain no subjects.

Trial 2 scores

Trial 1 scores	50	49	48	47	46	45	43-44	41-44	38-40	≤37	
49-50	432	19	2								453
48	127	9	1								137
47	84	18		1							103
46	78	12	1	1							92
45	58	4	2		1						65
44	35	7		2	1						45
42-43	51	14	8	1	4	1		1			80
40-41	20	11	6	5	2	1	2	3	1		51
37-39	11	7	5	5	1	4	5	3	4	1	46
≤36	4	3	8	1	4	1	13	9	20	63	126
	900	104	33	16	13	7	20	16	25	64	1198

x = definitely feigning by the TOMM manual's criterion (N=125)

x = definitely feigning based on study findings (N=36)

x = probably feigning based on study findings (N=89)

Figure 1. – ROC graph showing the discriminatory performance of four performance validity tests under the agnostic knowledge assumption. WMT = Word Memory Test; TOMM Tr 1 = Test of Memory Malingering Trial 1; CARB = Computerized Assessment of Response Bias; CVLTFC = California Verbal Learning Test-II Forced Choice Trial.

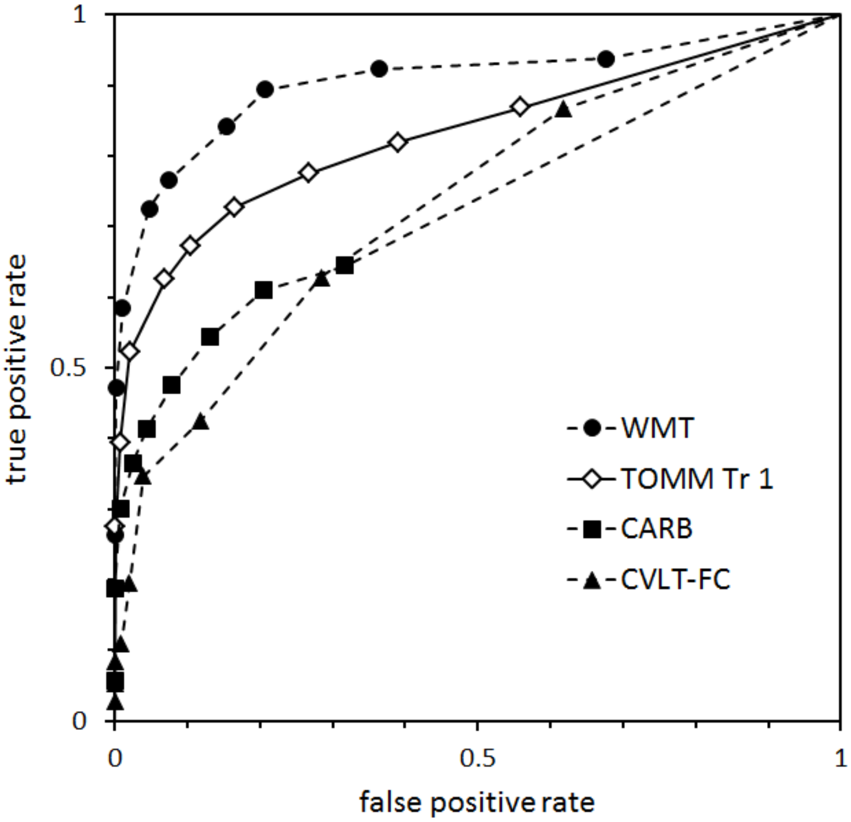


Figure 2. – ROC graph showing the discriminatory performance of four performance validity tests under the partial truth knowledge assumption. WMT = Word Memory Test; TOMM Tr 1 = Test of Memory Malingering Trial 1; CARB = Computerized Assessment of Response Bias; CVLTFC = California Verbal Learning Test-II Forced Choice Trial.

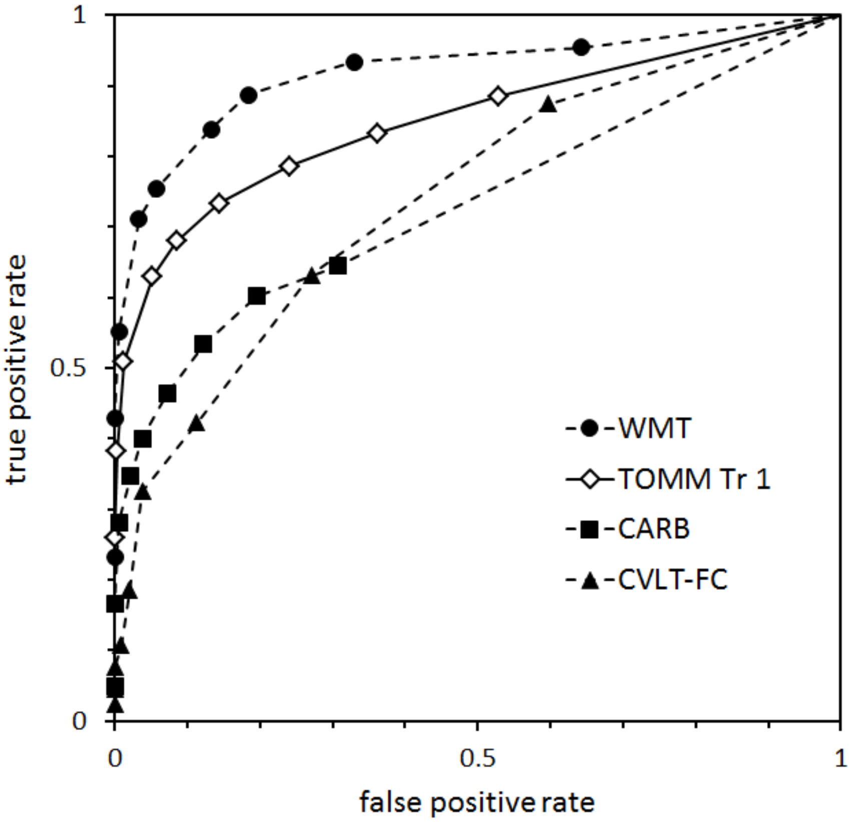


Figure 3. – ROC graph showing the discriminatory performance of four performance validity tests under the agnostic knowledge assumption. WMT = Word Memory Test; TOMM Tr 2 = Test of Memory Malingering Trial 2; CARB = Computerized Assessment of Response Bias; CVLTFC = California Verbal Learning Test-II Forced Choice Trial.

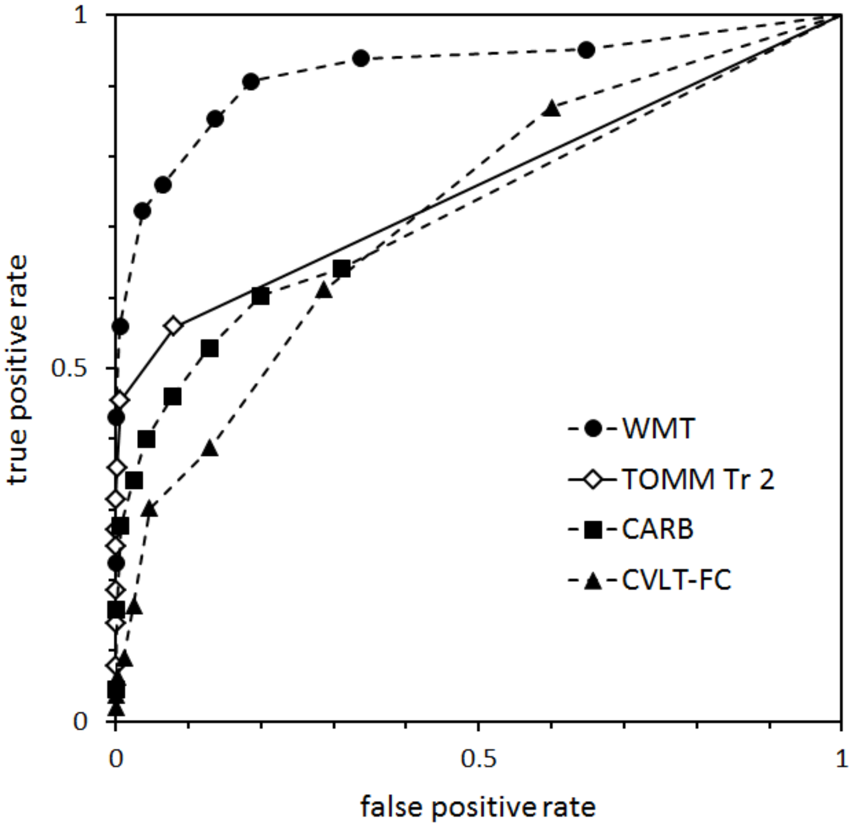


Figure 4. – ROC graph showing the discriminatory performance of four performance validity tests under the partial truth knowledge assumption. WMT = Word Memory Test; TOMM Tr 2 = Test of Memory Malingering Trial 2; CARB = Computerized Assessment of Response Bias; CVLTFC = California Verbal Learning Test-II Forced Choice Trial.

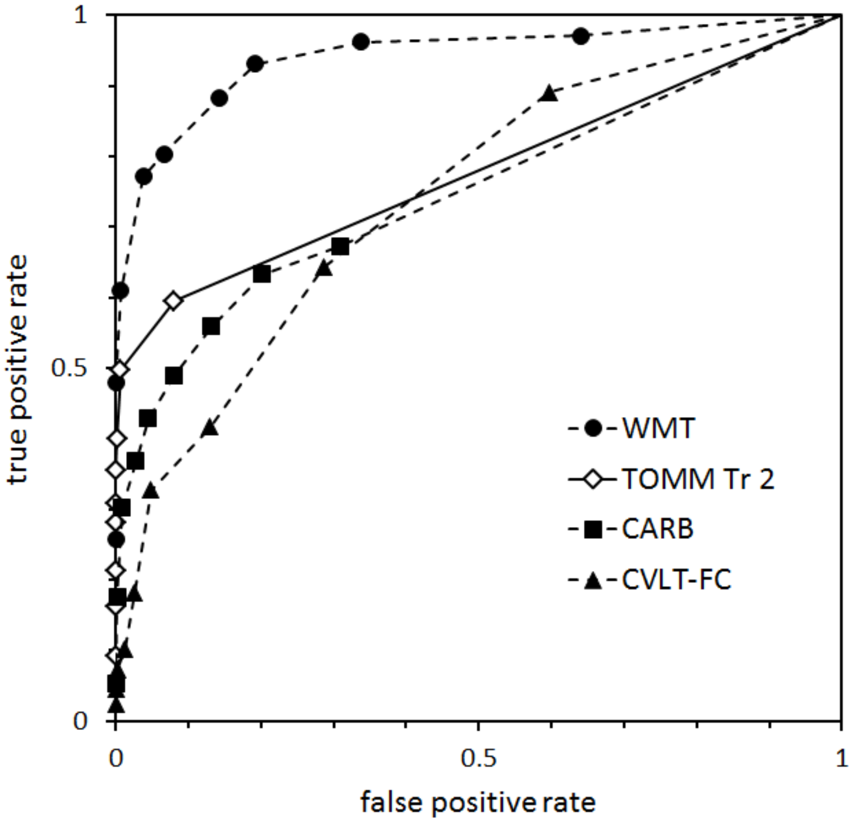


Figure 5. – ROC graph comparing the discriminatory performance of Trial 1 and Trial 2 of the Test of Memory Malingering under the agnostic knowledge assumption.

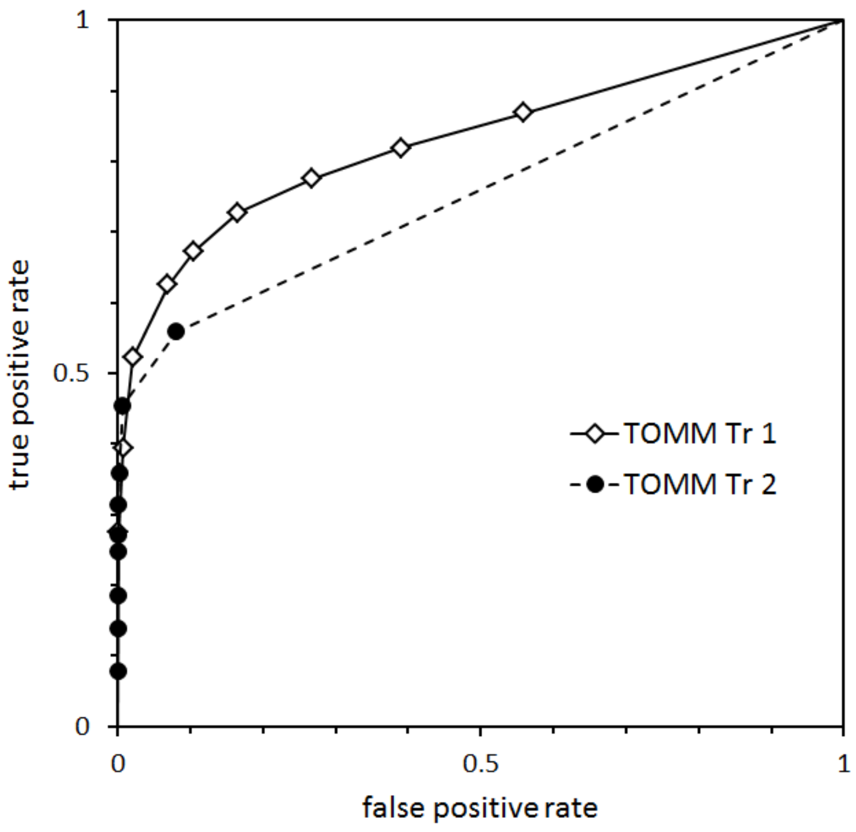
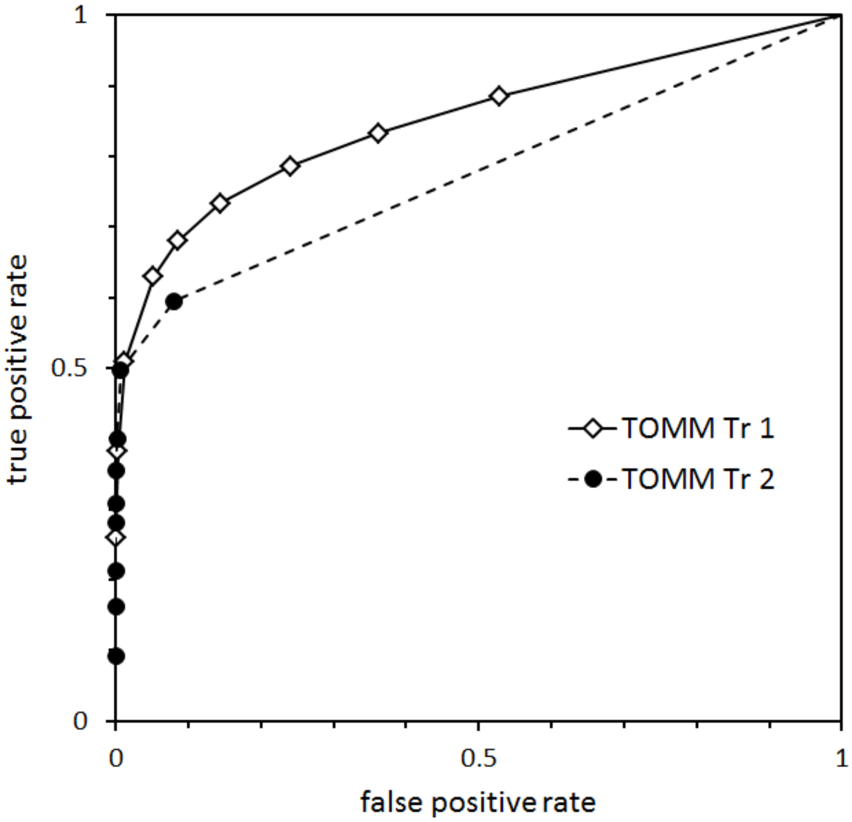


Figure 6. – ROC graph comparing the discriminatory performance of Trial 1 and Trial 2 of the Test of Memory Malingering under the partial truth knowledge assumption.


true positive rate
false positive rate
TOMM Tr 1
TOMM Tr 2